Ag84Mr

COMPARATIVE PERFORMANCE AND COSTS OF DRY ICE AND WATER ICE IN SHIPPING FRESH POULTRY

USDA
NAT'L AGRIC LIBRARY
2005 JUL 14 A 11:08

Marketing Research Report No. 906

Last copy

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
INFORMATION DIVISION
HYATTSVILLE, MARYLAND 20782

June 1971

ERRATUM

Marketing Research Report No. 906, "Comparative Performance and Costs of Dry Ice and Water Ice in Shipping Fresh Poultry"

Page 3, right column, 3d paragraph, 11th and 12th lines: *For* 0.26 lb., with a range from 0.25 to 0.27 lb. *read* 1.43 lb., with a range from 1.39 to 1.50 lb.

PREFACE

This study is part of a broad program of research by the Market Quality Research and Transportation and Facilities Research Divisions of the Agricultural Research Service on technical problems in the marketing of poultry.

Ralston Purina Co. of Berlin, Md., Waterville, Maine, and Nacogdoches, Tex., and McGehee's Poultry, Inc., Arcadia, La., supplied the plant facilities. Cellu-Products Co., Patterson, N.C., supplied packing material and technical consultation; E. J. Benson & Associates, Berkeley Heights, N.J., supplied technical assistance and consultation; Sinclair-Koppers Co., Pittsburgh, Pa., supplied the prototype polystyrene-foam boxes; and International Paper Co., Container Division, Whippany, N.J., supplied the prototype fiberboard boxes. B. T. Atherton, U.S. Department of Agriculture, assisted in obtaining samples and performing laboratory work.

Contents

Page
Summary 1
Introduction 2
Purpose 2
Storage studies 3
  Procedure 3
  Results and discussion 5
Commercial shipping studies 8
  Procedure 8
  Description of boxes and packing operations 9
  Costs 10
  Damage to boxes 13
  Poultry weight loss and temperature 13
  Various amounts and locations of dry ice snow 13
  Trade reaction 15
Discussion 15
Literature cited 16

Washington, D.C.   Issued February 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office,
Washington, D.C. 20402 — Price 20 cents

COMPARATIVE PERFORMANCE AND COSTS OF DRY ICE AND WATER ICE IN SHIPPING FRESH POULTRY

By LAWRENCE A. RISSE, *agricultural economist, Transportation and Facilities Research Division,*
and
JAMES E. THOMSON, *research food technologist, Market Quality Research Division, Agricultural Research Service*

SUMMARY

Comparisons were made of carbon dioxide (CO_2) and water ice as coolants in shipping boxes for poultry in storage and commercial shipping tests. In the storage tests, four types of boxes were tested: Wax-coated corrugated fiberboard, resin-impregnated corrugated fiberboard, expanded polystyrene foam, and wooden wirebound. In the commercial shipping tests, wax-coated corrugated fiberboard and expanded polystyrene-foam boxes were studied.

Costs and charges for packaging materials; packing, loading and unloading labor; coolant; and transport per hundredweight were: Dry ice-packed poultry in fiberboard boxes, $1.42; water ice-packed poultry in fiberboard boxes, $1.59; dry ice-packed poultry in polystyrene boxes, $1.52; and water ice-packed poultry in polystyrene boxes, $1.55. These costs for dry ice-packed poultry are based on 14 ounces (oz.) of dry ice snow per box.

The percentage of weight loss of poultry stored at 33° F. was not significantly different in fiberboard boxes with water or dry ice. However, it was significantly greater in polystyrene boxes with dry ice than in fiberboard boxes with either water or dry ice. Weight loss of poultry at 40° was significantly greater with dry ice than with water ice as a coolant, regardless of the type of box used. The percentage of weight loss of poultry from processing plant to receiver's warehouse in six commercial shipments was significantly higher for dry ice-packed poultry (6.3 percent) than for water ice-packed poultry (5.5 percent).

Packaged chicken (whole and cut up) which had been stored in water ice before packaging showed significantly higher weight loss during storage in refrigerated display case than packaged chicken which had been stored without coolant or in dry ice before packaging.

The average temperature of poultry on arrival at the receiver's warehouse was significantly higher for dry ice-packed poultry (37° F.) than for water ice-packed poultry (33°) in six commercial shipments.

Receivers at the central warehouse and retail stores preferred the dry ice-packed poultry because the boxes were lighter in weight, had less drainage in box, were easier to handle, and appeared more sanitary than the water ice-packed poultry.

General adoption of packing and shipping dry ice-packed poultry instead of water ice-packed poultry in fiberboard boxes would have resulted in an estimated annual savings of approximately $15.7 million for 1968. Most of this saving would have resulted because 25 percent more of the dry ice-packed poultry could have been loaded per truck than water ice-packed poultry.

INTRODUCTION

Since 1951, the Nation's commercial production of broilers has been steadily increasing. In 1968, 2,599 million broilers, or 9,260 million lb., were produced in the United States (*12*)[1]. Approximately 80 percent of U.S. broiler production is shipped water ice-packed, mostly in wirebound wooden veneer boxes or moisture-resistant corrugated fiberboard boxes. In most commercial shipments, however, about 25 to 35 percent of the load is water ice.

Lemmons described a commercial system of using carbon dioxide in which about one-half pound of dry ice snow was placed inside corrugated boxes, an absorbent pad was placed on top the snow, and the poultry was packed in the box.[2] Good product appearance and characteristics were found in commercial shipments. Burkhart (*1*) described a commercial system in which prepackaged chicken was shipped in corrugated boxes using dry ice snow as coolant. McKee and others (*7*) found greater product weight loss in dry-packed than in ice-packed chicken during storage; water from melting ice in ice pack retarded moisture loss from the product.

Davis (*4*) found that iceless packs of fresh broilers cut shipping costs; payloads were up to 40 percent greater due to elimination of ice. He also found that shipping broilers in refrigerated trucks without ice resulted in somewhat greater product weight loss than shipping ice-packed poultry, but cut-up loss at the retail level was less in chicken shipped without ice.

May and others (*6*) found higher overall product weight loss during storage in dry-packed chicken compared with ice-packed. However, in the later stages of storage, drip fluid accumulated in the bottoms of the fiberboard boxes used for the dry-packed chicken, while almost all fluid drained completely from the wooden ice-packed boxes, resulting in less loss in weight of dry-packed than of ice-packed chicken. Shantz and others (*9*) found that at 40° F. storage, moisture loss was higher in dry than in ice pack.

PURPOSE

The overall purpose of this study was to determine the performance and cost of carbon dioxide snow as a coolant as compared with water ice in the shipping and storage of fresh chilled poultry. The objectives of the storage studies were to determine:

(1) The relation of storage temperature, type of coolant, and box material to carcass weight loss during storage.

(2) The effect of type of coolant used in boxes on cutting-up loss and retail packaged product weight loss of poultry.

The objectives of the commercial shipping studies were to determine:

(1) The comparative cost estimates of packing and shipping dry-ice and water-ice packed poultry.

(2) Temperature and carcass weight changes of dry- and water-ice packed poultry.

(3) Trade reaction to dry- and water-ice packed poultry.

---

[1] Italic numbers in parentheses refer to Literature Cited, p. 16.

[2] LEMMONS, T. J. FRESH POULTRY PACKAGED BY THE CO_2-CELL METHOD. 1966. Speech presented at annual meeting of the National Poultry, Butter, and Egg Assoc., Chicago, Ill., Oct. 1966.

STORAGE STUDIES

Procedure

These studies were conducted in a commercial processing plant in Maryland, and in the storage facilities and laboratories of the Agricultural Research Service at Beltsville, Md., in 1967, 1968, and 1969. Analyses of variance and multiple-range tests (*5*) were used when appropriate to evaluate data.

Experiment 1.—Filled boxes of packed chicken fryers with giblets were removed from the processing line at the poultry plant at the point between the weighing scale and icing operation. Only boxes containing birds in the 2.2- to 2.4-lb. category were selected. The birds were removed from these boxes and repacked rapidly into the test boxes. When they were repacked, the temperature in a deep portion of the breast meat was measured.

Seven combinations of box material and coolant were evaluated. The following code refers to each box material-coolant combination:

Code	Box material	Coolant
FC–20I	Wax-coated corrugated fiberboard	20 lb. of water ice.
FC–S	do	2.2 lb. of dry ice snow.
P–B	Expanded polystyrene	1.1 lb. block of dry ice.
P–S	do	2.2 lb. of dry ice snow.
FR–20I	Resin wax-impregnated corrugated fiberboard	20 lb. of water ice.
WB–20I	Wirebound wooden	do
P–15I	Expanded polystyrene	15 lb. of water ice.

The wirebound box used in the tests had inside dimensions of 19 by 17 by 11 in. Its tare weight, when dry and empty, including a parchment paper liner, averaged 5 lb., with a range from 4.6 to 6.0 lb. The boxes were wood veneer and made as follows: four side slats, two on each side; three top slats; three bottom slats; four 15-gage binding wires; six end slats, three on each end; and eight cleats, four on each end.

The wax-impregnated corrugated fiberboard boxes were of full-telescope design with inside dimensions of 22 by 14 by 11 in. Two 0.2- by 1.0-in. drainage slots were in each end of the box, and a 0.2- by 3.0-in. slot was in the center of the top cover. The tare weight of these boxes, when dry and empty, averaged 3.4 lb., with a range from 3.3 to 3.5 lb.

The wax-coated corrugated fiberboard boxes were of part-telescope design. Inside dimensions of these boxes were 21 by 17 by 10 in. when used with water ice. Two 0.2- by 0.8-in. drainage slots were in each end of the box. This type of box, when used with dry ice, had inside dimensions of 21 by 17 by 8 in. and no drainage slots. The average tare weight of these boxes, when dry and empty, was 3.5 lb., with a range from 3.3 to 3.6 lb.

The polystyrene boxes were of part-telescope design and had inside dimensions of 24 by 14 by 10 in. Sides, tops, and bottoms were 1.0 in. thick. The bottom of this box was molded so that melted ice water and drippings from the birds drained to the ends of the box where four 0.6-in.-diameter holes were located at the junction of each side, end, and bottom panel. There were no holes in this box when used with dry ice. The average tare weight of these boxes, when dry and empty, was 0.26 lb., with a range from 0.25 to 0.27 lb. The polystyrene box is not reusable.

An absorbent pad, 15.6 by 21.3 in., was placed in the bottom of each test box in which dry ice was used as the coolant. This pad was constructed of a top layer of high wet-strength, low-absorbency kraft paper, and 10 layers of high wet-strength, high-absorbency cellulose wadding.

The number of each type of box-coolant combination packed were: 12 boxes each of codes FC-20I, FC-S, P-B, P-S, and 6 boxes each of P-S, FR-20I, WB-20I, and P-15I.

To pack the boxes in which water ice was to be used as the coolant, about 23 chickens (about 55 lb.) were placed breast up, legs toward center in two layers in each box. The exact net weight was obtained, then the appropriate amount of water ice was placed on top the poultry and the box was closed.

To pack the boxes in which dry ice snow was to be used as the coolant, 2.2 lb. of snow was first dispensed into the bottom of each box from a hooded nozzle leading from a specially modified dry ice snow forming machine. An absorbent pad was then placed over the snow, and about 55 lb. of poultry was placed in the box. The exact net weight was obtained and the box was closed.

To pack the boxes in which a block of dry ice was to be used as the coolant, a 1.1 lb. block of dry ice was first placed in a separate small expanded polystyrene "ice bucket" with loosely fitting top. An absorbent pad was then placed in the bottom of the box to be packed, the ice bucket placed on top the pad in a corner of the box, and then about 55 lb. of poultry were placed in the box. The exact net weight of the box was obtained and the box was closed.

All boxes were loaded into a mechanically refrigerated truck and transported approximately 150 miles from the plant to the cold-storage facilities at Beltsville, Md. Temperature inside the truck during the trip was maintained at 33° ± 6° F.

Upon arrival at Beltsville, all the test boxes were distributed into two temperature-controlled storage rooms as follows: Six each of all seven box-type coolant combinations were placed in the 40° ± 1° F. room, and six each of FC-20I, FC-S, P-B, and P-S in the 33° ± 1° room. Three stacks each two boxes high of each box-type coolant combination were placed on wooden racks in the storage rooms. Stacks of each type were distributed throughout the room to minimize the effect of possible variations in air temperature.

Temperatures of the air in both storage rooms, inside the boxes, and in deep portions of the carcasses in the top fiberboard and polystyrene boxes in the 33° F. storage room were measured with a 20-point potentiometer recorder.

After 3, 6, and 9 days of storage, one stack of two boxes of each box-type coolant combination was removed from each storage room. Net weight of poultry in each of these boxes, and the weight of ice remaining in the boxes in which water ice was the coolant were obtained.

The entire procedure was replicated twice.

Experiment 2.—Twenty-four full boxes of ice-packed chicken fryers of the same size as in experiment 1 were obtained at the same processing plant. These boxes were then placed inside a refrigerated truck and transported to Beltsville. Average temperature in a deep portion of the breast meat upon arrival at Beltsville was 36° F. The birds were then rapidly repacked into test boxes.

Four combinations of box material and coolant were evaluated: FC-S, P-S, expanded polystyrene with no coolant (P-O), and WB-20I.

The dry ice snow was formed by crushing chips from a block of dry ice to a very fine powder.

An absorbent pad of the same type as used in experiment 1 was placed in the bottom of all boxes except WB-20I.

The birds were repacked and weights were obtained by the same procedure as in experiment 1.

Twelve stacks of two boxes of each combination were then placed on wire racks in a storage room maintained at 41.4° ± 3.6° F. These stacks were distributed throughout the room to minimize the effect of possible variations in air temperature in the room.

Temperatures in the air of the storage room and in the deep portion of carcasses in each box type were obtained by thermocouples of a 20-point potentiometer recorder.

After 3, 6, and 9 days of storage, one stack of two boxes of each type was removed from the room. Net weight of poultry was determined as in experiment 1.

The entire procedure was replicated twice.

Experiment 3.—Chickens with giblets from the end of the processing line (before icing) were weighed individually, then 24 were packed into each of four fiberboard boxes. No coolant was placed in the first box, 20 lb. of water ice in the second, 1.1 lb. of dry ice in the third, and 5.0 lb. of dry ice in the fourth.

The boxes were wrapped in canvas, placed in a truck, and transported to the Beltsville storage facility. The trip from the processing plant to the storage facility took about 2½ hours. Upon arrival at Beltsville, the boxes were placed in a storage room maintained at 37° F. and held for 3 days. Twelve birds from each box were then removed, weighed individually, and packaged as whole birds in a stretchable 1.5 mil polyvinyl-chloride film bag. This bag was mechanically stretched and the bird inserted, the bag was then relaxed to fit the product. The other 12 birds in each box were each individually weighed; then they were cut up into seven pieces (wings, thighs with drumsticks, breast with ribs, back in two pieces), weighed again, then packed in a fiber tray with an 8-layer cellulose wadding soaker pad, and film packaged.

All packaged birds were then stored in an open-top retail display refrigerator in which the average air temperature was 42° F. Temperatures in the packages and in the air in different locations throughout the display case, and in different parts of representative individual birds were obtained by thermocouple insertions from a 20-point potentiometer recorder. After 2 days, half of each lot was removed from the display case, unpackaged, and weighed. The other half was removed after 3 days, unpackaged, and weighed.

The entire procedure was replicated twice.

Results and Discussion

Ice-Retention Studies

In experiment 1 (table 1) in the 40° F. storage room, wirebound boxes showed the least average retention of water ice of all boxes tested; resin-impregnated fiberboard boxes were next, followed by wax-coated fiberboard boxes; and polystyrene boxes showed the greatest retention. The last two types of boxes were not significantly different from each other. Wax-coated fiberboard boxes stored at 33° showed greater retention than boxes stored at 40°. Average retention was greatest after 3 days' storage, intermediate after 6 days, and least after 9 days, for all box types.

Although the bottom boxes generally retained significantly more water ice than top boxes in the stacks (bottom 5.6 lb. compared with top 5.0 lb.), the top wax-coated fiberboard boxes stored at 33° F. tended to show greater retention of ice than the bottom boxes in the same stacks (table 1).

TABLE 1.—*Water ice remaining on chicken carcasses in shipping boxes (experiment 1)*[1]

Box material and amount of ice added at packing	Storage temperature	Stack position of shipping box	Water ice retained after stored—			Overall mean
			3 days	6 days	9 days	
	°F		*Lb.*	*Lb.*	*Lb.*	*Lb.*
Wax-coated fiberboard, 20 lb. ice	33	Top	14.7 n	13.9 m	12.5 l	13.4 d
		Bottom	14.3 mn	13.0 l	11.7 k	
Wax-coated fiberboard, 20 lb. ice	40	Top	8.4 h	1.3 bc	0 a	4.0 c
		Bottom	10.8 j	3.5 e	0 a	
Resin-impregnated fiberboard, 20 lb. ice	40	Top	6.8 g	.4 ab	0 a	3.3 b
		Bottom	9.2 i	2.6 d	0 a	
Wirebound wooden, 20 lb. ice	40	Top	5.3 f	.2 a	0 a	2.0 a
		Bottom	5.9 f	.4 a	0 a	
Polystyrene, 15 lb. ice	40	Top	7.7 h	3.5 e	.4 a	4.2 c
		Bottom	7.9 h	4.0 e	1.5 c	
Overall mean			9.0 a	4.4 b	2.6 c	

---

[1] Mean of 2 boxes. Means enclosed by lines; those followed by different letters are significantly different at the 5-percent level.

Although less water ice was added to the polystyrene boxes than to the other types, they retained amounts of water ice as great as or greater than the other types stored at the same temperature. Polystyrene boxes thus retained a greater percentage of ice than the other types.

Carcass Percentage Weight Loss and Temperature Changes

In experiment 1, carcasses in all box types using dry ice as coolant showed significantly greater weight loss than carcasses in all box types using water ice as coolant, with one exception. Carcasses in the wax-coated fiberboard boxes using dry ice snow stored at 33° F. showed no significant difference in weight loss from carcasses stored in boxes using water ice (table 2). The reason for this may have been that fiberboard, having lower insulation properties than polystyrene, allowed a more rapid temperature reduction in carcasses, with faster firming of the carcass tissue, and thus retarded moisture loss. The carcass temperature was in the vicinity of 41° when the boxes were packed and the amount of dry ice used was too small (and was not intended) to significantly affect carcass temperature. The polystyrene boxes thus shielded the carcasses therein from the lower storage room temperature for a period long enough to allow relatively high weight loss through moisture weepage.

Temperature recorder readings showed that at storage room temperature of 33° F. about 10 hours were required for inside box air temperature and about 22 hours for deep meat temperature to be reduced from 41° to 34° in fiberboard boxes, while more than 25 hours were required for inside box air temperature and 50 hours for deep meat temperature to be reduced the same amount in the polystyrene boxes.

When leakage occurred in fiberboard boxes with dry ice snow and drip did not accumulate in the bottom, the loss in carcass weight tended to be greater.

In experiment 1 also the mean weight loss after 3 days (4.6 percent) was found to be significantly less than after 9 days (5.2 percent). Mean weight loss after 6 days was 5 percent, which was not significantly different from either 3 or 9 days. At 40° F. storage temperature, carcass weight loss as a function of box material was not significantly different when water ice was used as the coolant (table 2). This result differed somewhat from findings of Thomson and others (*11*) in which carcasses packed in ice in wirebound boxes were found to lose significantly greater weight than those in ice in fiberboard and polystyrene boxes. It agreed with findings of Risse (*8*) in this respect. These results also showed that resin-wax-impregnated fiberboard boxes were not significantly different in carcass weight loss from wax-coated fiberboard.

TABLE 2.—*Weight loss in chicken carcasses in shipping boxes after storage up to 9 days (experiment 1)*[1]

Box material	Coolant	Weight loss after stored at— 33°F.	40°F.	Overall mean
		Percent	*Percent*	*Percent*
Wax-coated fiberboard	20 lb. water ice	4.1 a	4.0 a	4.0 a
Wax-coated fiberboard	2.2 lb. dry ice snow	4.2 a	5.6 b	4.9 b
Polystyrene	1.1 lb. dry ice block	5.4 b	5.5 b	5.5 c
Polystyrene	2.2 lb. dry ice snow	5.5 b	5.1 b	5.3 bc
Resin-impregnated fiberboard	20 lb. water ice	—	3.5 a	
Wirebound wooden	20 lb. water ice	—	4.1 a	
Polystyrene	15 lb. water ice	—	3.8 a	

---

[1] Mean of 2 boxes. Means enclosed by lines; those followed by different letters are significantly different at the 5-percent level.

In experiment 2, the carcasses were chilled from about 41° F. when at the processing plant to about 36° when packed into the test boxes in Beltsville. A primary purpose of chilling before packing was to determine whether a lower than usual carcass temperature might result in less weight loss during storage. Neither moisture nor substantial cooling effect was provided by the small amount of dry ice used in these experiments. The rather high and somewhat variable storage temperature used in experiment 2 represented a less than ideal, but perhaps too commonplace, situation.

The lower overall losses in carcass weight during storage in experiment 2 than in experiment 1 resulted from the loss which occurred during prepacking chilling in experiment 2; the weights before storage in experiment 1 included the weight of moisture which was lost between plant and packing in experiment 2.

Although carcasses were colder at packing time in experiment 2, the same relationship was found as had occurred in experiment 1; water ice-packed birds showed less weight loss during storage than dry ice-packed ones (table 3). The overall percentage differences between average weight losses of dry ice-packed (either block or snow) and water ice-packed birds were very similar in experiments 1 and 2. In experiment 1 the weight loss for dry ice-packed birds averaged 38 percent higher than for water ice-packed birds; in experiment 2, the weight loss for dry ice-packed birds was 39 percent higher.

TABLE 3.—*Weight loss of chicken carcasses in shipping boxes after storage at 41.4° ±3° F. (experiment 2)*[1]

Box material	Coolant	Weight loss after stored— 3 days	6 days	9 days	Overall mean
		Percent	*Percent*	*Percent*	*Percent*
Wax-coated fiberboard	2.2 lb. dry ice snow	2.5	3.5	3.8	3.3 b
Polystyrene	2.2 lb. dry ice snow	2.9	3.5	3.8	3.4 b
Polystyrene	None	2.8	3.7	3.6	3.4 b
Wirebound wooden	20 lb. water ice	1.9	2.4	3.4	2.6 a
Overall mean		2.6 a	3.3 b	3.6 b	

[1] Mean of 4 boxes. Means within a column or row followed by different letters are significantly different at the 5-percent level.

Difference in percentage of weight loss was not significant between carcasses stored with no coolant in polystyrene boxes and those stored in polystyrene or fiberboard with dry ice snow.

Significantly less weight loss occurred after 3 days than after 6 or 9 days; no significant differences occurred between 6 and 9 days.

In experiment 2 (storage room temperatures 41.4° ± 3.6° F.), average temperature over the 9 days of storage in a deep portion of the carcasses in bottom wirebound boxes was 38°; this temperature was significantly lower ($P= 0.05$) than that recorded in the top wirebound and bottom polystyrene boxes with dry ice (both averaged 40°). The temperature in the last two types of boxes was significantly lower ($P=0.05$) than in both the top and bottom fiberboard and top polystyrene packed with dry ice, all of which averaged 41°. The polystyrene boxes with no coolant (top averaged 42° and the bottom 44°) had significantly higher ($P= 0.05$) carcass temperatures than all the other types of boxes and were, in fact, higher than ambient room air temperature. The reason for this may be explained by the advanced degree of spoilage reached by carcasses in these boxes and the concomitant high heat production as a result of microbial metabolism. This heat was trapped in these well-insulated boxes and produced higher than ambient temperature conditions.

In experiment 3, a trend was found after storage in shipping boxes which corresponded to the significant findings in experiments 1 and 2, in which birds held in water ice lost less weight than those in dry ice or no coolant. Neither the type nor the amount of coolant in the shipping boxes had a significant effect on cutting-up weight loss (table 4). After film packaging and storage in the display-type refrigerator, the birds which had been held with no coolant before packaging lost significantly less ($P=0.05$) weight than those held in either 1.1 or 5.0 lb. of dry ice or in 20 lb. of water ice. The birds which

TABLE 4.—*Weight losses of chicken carcasses after specified periods of storage (experiment 3)*[1]

Box coolant	In shipping boxes for 3 days at 37° F.	Cutting up	Packaged and in display refrigerator at 42° F.				Overall mean	Total mean
			Cut up		Whole			
			2 days	3 days	2 days	3 days		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
None	4.6	0.2	4.1	4.5	0.5	0.9	2.5 a	7.0 a
20 lb. water ice	3.9	.2	4.5	5.3	.9	1.4	3.0 c	7.0 a
1.1 lb. dry ice	4.4	.2	4.5	4.7	.6	1.0	2.7 b	7.1 a
5 lb. dry ice	4.5	.2	4.5	4.5	.8	.9	2.7 b	7.2 a
Overall mean	...	...	4.4 b	4.7 b	0.7 a	1.1 a	...	...

[1] Mean of 2 boxes. Bird weight when packed at plant or before cutting up or packaging, minus weight after storage or cutting up, divided by former, times 100. Means within a column or row followed by the same letter are not significantly different at the 5-percent level.

had been held in dry ice lost significantly less (P=0.05) weight after packaging than those held in water ice. Packaged whole birds lost significantly less (P=0.01) weight than packaged cut-up birds. Weight loss of birds packed whole and cut up after 2 days of storage (2.6 percent) was significantly less (P=0.01) than after 3 days (2.9 percent).

In the two replications of experiment 3, all practical precautions were taken to keep factors the same; the processing plant, time of day, location of sampling, type and weight category of sample birds, and method of handling and shipping were the same in both replications. Nevertheless, significantly lower (P=0.01) weight loss occurred in the birds of replicate 1 than 2 as measured at all stages of the experiment. This finding illustrates the importance of factors before and during processing on the weight losses which may occur during shipping and storage.

Calculation and statistical analysis of total weight loss after display refrigerator storage based on weight of these birds in the processing plant showed no significant difference in loss as a function of amount or type of coolant. The greater weight loss of dry ice-packed than of water ice-packed birds (measured after shipping) was thus compensated by the smaller weight loss of dry ice-packed birds during display case holding.

Temperatures were different at various locations on the same bird and among birds in different locations in the display refrigerator. The row of packages nearest the cold air inlet slot showed localized freezing, while other parts of the same birds were as high as 39° F. Other birds in warmer locations in the display case showed temperatures ranging from 39° in one part to 50° in another part of the same bird. Air temperature in the room in which the display case was located was about 70° and air movement was minimal; no fans or air-conditioner blowers operated in the room. Temperature variability in self-service display cases was also found by Butler and others (*2*); they reported that the top surface of a ½-inch thick steak averaged 3° higher than the rack surface.

COMMERCIAL SHIPPING STUDIES

Procedure

Cost of packaging materials for the two types of boxes was obtained from manufacturers and suppliers. All costs of packaging material are based on prices per thousand for carlot orders.

Direct labor requirements for assembling, packing, and loading the boxes were obtained by conducting time studies in two poultry processing plants. Direct labor requirements for unloading the boxes were obtained by conducting time studies at two receivers' warehouses. Other operations not affected by type of box were not included in this study. A wage rate of $2 per hour was used to calculate labor costs.

Transport charges for shipping the boxes were calcualated from truck operating costs reported by Camp (*3*).

In 1968, two truck shipments of water ice-packed and dry ice-packed poultry were made from each of three processing plants (in Texas, Louisiana, and Maine) to three receivers (in Indiana, California, and New York). In each shipment, five each of water ice-packed and dry ice-packed polystyrene and fiberboard boxes (test boxes) were packed with approximately 65 lb. of fryer chickens of comparable quality and size. The ice-packed fiberboard boxes were packed with 25 lb. of crushed ice and the polystyrene boxes with 15 lb. Approximately 14 oz. of dry ice snow was discharged into the dry ice-packed boxes and an absorbent pad placed on top the dry ice snow before packing the poultry. The poultry and ice were weighed at the time of packing. Temperatures of the birds at the time of packing were taken by inserting a thermometer into the breast portion of the carcass. The test boxes were loaded in the left corner of the last stack in each of the shipments. The rest of each load was generally loaded with dry ice-packed fiberboard boxes. After all boxes were loaded into a refrigerated trailer, a 3-minute-and-20-second charge (200 lb.) of dry ice snow was discharged into the trailer. This dry ice snow immediately brought the air temperature inside the trailer down below 30° F. The thermostat on the refrigeration unit of the truck was set at 30°.

At the receiver's warehouse after the test boxes were removed from the trucks, the contents of these boxes were removed and the carcasses weighed. Temperatures of two birds in each test box in each shipment were taken by inserting a thermometer into the breast portion of each carcass.

Also in 1968, two truck shipments of water ice-packed and dry ice-packed poultry were made from one processing plant (Maine) to one receiver (New York) to compare the effects of different amounts of dry ice snow per box and location of dry ice snow in the box on the poultry. In each shipment, 21 fiberboard boxes were packed with fryer chickens of comparable quality and size. There were three boxes of water ice-packed poultry, three boxes each of dry ice-packed poultry with 14, 32, and 48 oz. of dry ice snow in bottom of box, and three boxes each of dry ice-packed poultry with 14, 32, and 48 oz. of dry ice snow on top the poultry. Two absorbent pads were used in the boxes with dry ice snow on top the poultry; one on the bottom of the box and the other on top the poultry, between the poultry and the dry ice snow. At the receiver's warehouse, temperatures of four birds in each of the boxes in each shipment were taken.

Comments were obtained from the three receivers and eight retailers.

An analysis of variance was used to test differences in temperature and loss of weight of poultry in the six shipments.

Description of Boxes and Packing Operations

The polystyrene boxes and wax-coated corrugated fiberboard boxes were the same as those described on page 3.

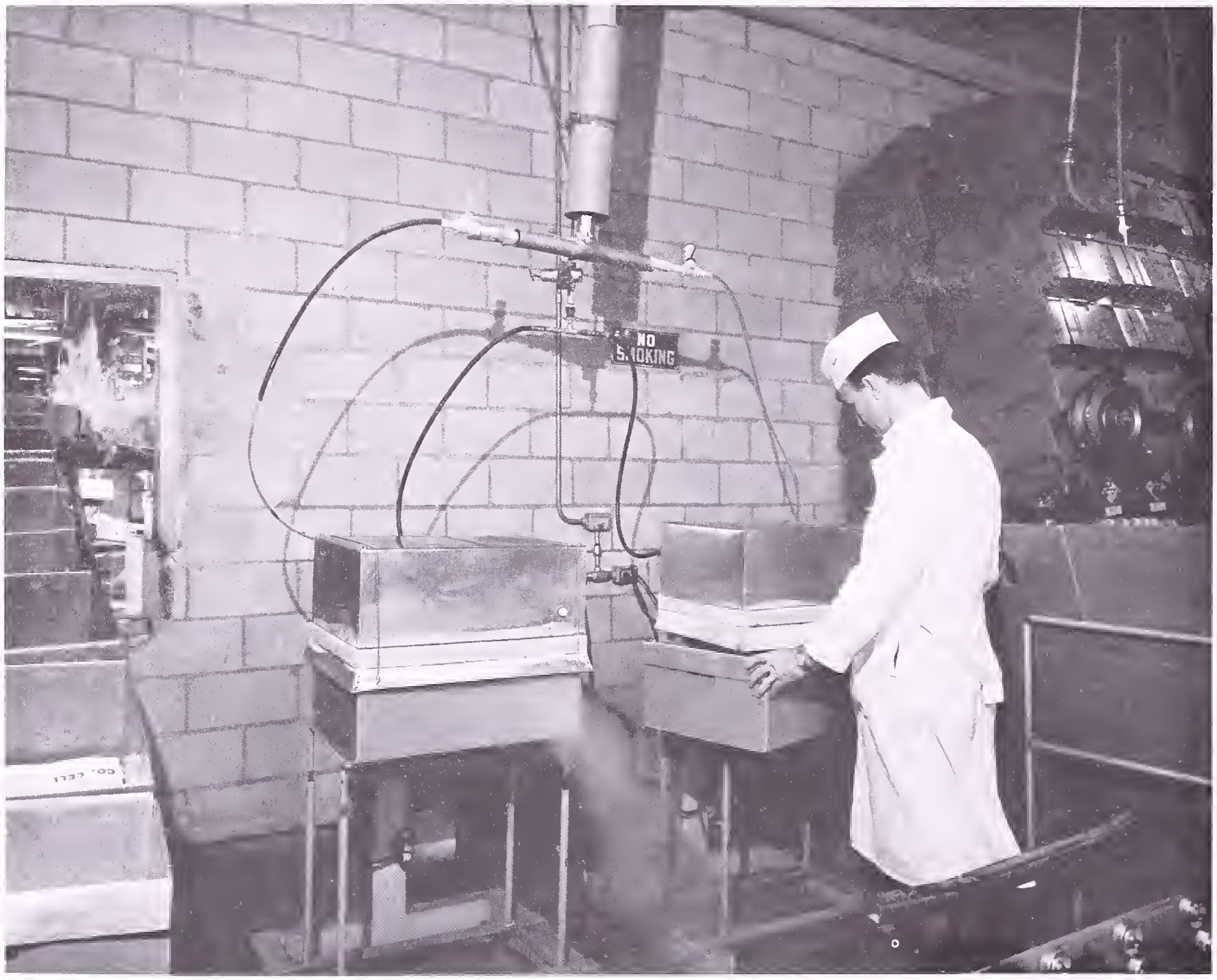
The fiberboard boxes were received from the manufacturer in knocked-down flat bundles. Each box was assembled with a semiautomatic stapling machine.

The fiberboard boxes for water ice-packed birds were then conveyed directly to the packing station. The number of birds per box varied according to the net weight of poultry packed. Generally, birds were packed two layers deep with two 6-bird rows per layer, or a total of 24 birds per box. After the boxes were filled, they were conveyed to a scale and weighed. Allowances for average tare weight (other than the test boxes) and shrinkage were made, and labels with net weight, count, and grade were stapled to one end of the box. The box was then iced and closed by placing a part-telescope lid over the bottom of the box.

The polystyrene boxes were received preassembled from the manufacturer. These boxes were packed in the same way as the fiberboard boxes except that less water ice was used.

In packing the dry ice-packed boxes, approximately 14 oz. of dry ice snow was discharged into the bottom of both the fiberboard and polystyrene boxes first (fig. 1). An absorbent pad was then placed on top the dry ice. The boxes were then conveyed to the packing area where the box was packed with birds and immediately closed.

The filled boxes, both the fiberboard and polystyrene, were either conveyed directly to the



BN-37145

FIGURE 1.—Discharging dry ice snow into fiberboard boxes.

loading dock or stacked on pallets and placed in storage. At the loading dock, the boxes were loaded one at a time into the truck. Approximately 200 lb. of dry ice snow was discharged into the truck immediately after loading, which brought the temperature inside the truck down to below 30° F. (fig. 2).

Costs

Packaging Materials

The corrugated fiberboard boxes used for water ice-packed and dry ice-packed poultry cost 47.8 and 46.7 cents per box, respectively. The polystyrene box, which is still in the stage of development, was not available in commercial quantities. Therefore, no market price has been established for the box. The manufacturer estimated, however, that the price of this box delivered to the processing plant would be approximately 55 cents per box.

Direct Labor for Packing, Loading, and Unloading

The direct labor costs for packing, loading, and unloading fiberboard boxes would be about 1.3 cents more than for polystyrene boxes, either water ice-packed or dry ice-packed (table 5). The difference was caused by the additional time required for assembling the fiberboard boxes.

Labor for packing, loading, and unloading dry ice-packed boxes would cost 0.4 cent more than for water ice-packed boxes, either fiberboard or polystyrene (table 5). The additional time required for inserting the absorbent pad into the empty box and blowing dry ice snow into the truck after loading accounted for the higher cost.

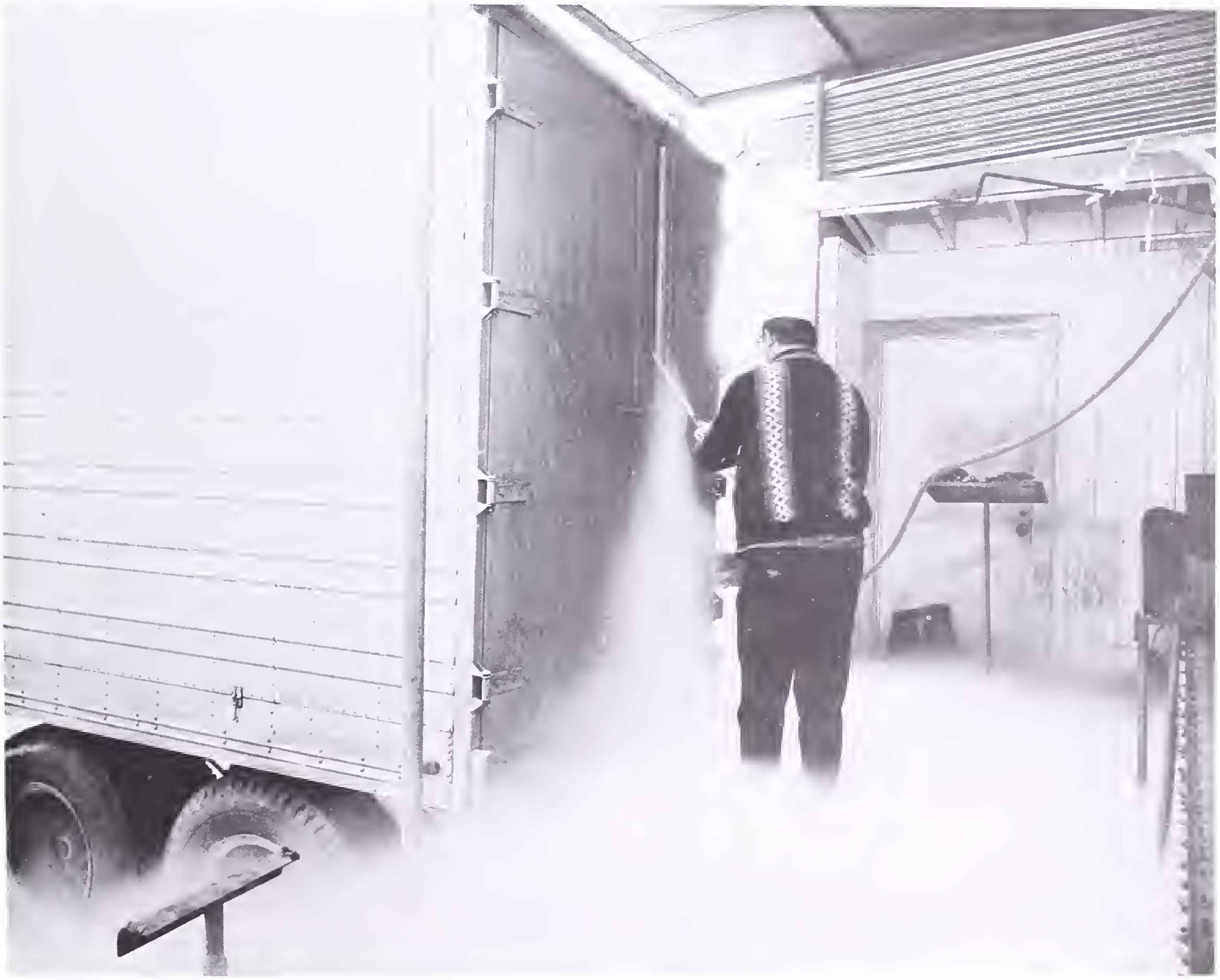
Water Ice and Dry Ice Snow

The cost for 25 lb. of water ice packed in fiberboard boxes was 6.3 cents per box and for 15 lb. packed in polystyrene boxes, 3.8 cents. The cost of crushed water ice was one-fourth cent per pound.

The cost of dry ice snow used, both in the fiberboard and polystyrene boxes and discharged into the truck, was 5 cents per pound. The cost of CO_2 gas is approximately $50 per ton, and 2 pounds of CO_2 gas is required to make 1 pound of dry ice snow. Additional dry ice snow in the box would increase the cost by 5 cents per pound of CO_2 snow added.

Transport

In most truck shipments of poultry, the trailers are not filled to full cubic capacity because of legal restrictions on maximum weights. The gross weight of the water ice-packed polystyrene boxes with poultry is 12 lb. less—10 lb. of ice and 2 lb. of tare weight—than that of ice-packed fiberboard boxes with poultry. The gross weight of the dry ice-packed polystyrene boxes with poultry is 2 lb. less than that of dry ice-packed fiberboard boxes.



BN-37146

FIGURE 2.—Discharging dry ice snow into the loaded truck.

TABLE 5.—*Direct labor costs to pack, load, and unload water ice-packed and dry ice-packed poultry in fiberboard and polystyrene-foam boxes, by specific operations, 2 processing plants, 1968*[1]

Operation	Fiberboard box				Polystyrene box[2]			
	Water ice-packed		Dry ice-packed		Water ice-packed		Dry ice-packed	
	Labor	Cost	Labor	Cost	Labor	Cost	Labor	Cost
	Man-minutes	*Cents*	*Man-minutes*	*Cents*	*Man-minutes*	*Cents*	*Man-minutes*	*Cents*
Assembling box	0.42	1.40	0.42	1.40				
Inserting pad	([3])	([3])	.11	.37	([3])	([3])	0.11	0.37
Inserting dry ice snow in box	([3])	([3])	.20	.67	([3])	([3])	.20	.67
Filling	.68	2.27	.68	2.27	0.68	2.27	.68	2.27
Weighing and labeling	.22	.73	.22	.73	.22	.73	.22	.73
Icing	.20	.67	([3])	([3])	.20	.67	([3])	([3])
Closing	.12	.40	.12	.40	.12	.40	.12	.40
Stacking and loading	.18	.60	.18	.60	.20	.67	.20	.67
Blowing dry ice snow in truck	([3])	([3])	.01	.03	([3])	([3])	.01	.03
Unloading	.15	.50	.15	.50	.16	.53	.16	.53
Total	1.97	6.57	2.09	6.97	1.58	5.27	1.70	5.67

[1] Includes 15-percent allowance for fatigue and personal time. Average wage rate was $2 per hour.

[2] Delivered to the processing plant ready for packing.

[3] None used.

Based on a legal load of 40,000 lb., the following number of boxes of poultry can be loaded in a typical truck shipment.

Type of box and coolant	Per load	
	Number of boxes	Weight
		Lb.
Polystyrene:		
Water ice packed	490	31,850
Dry ice packed	592	38,480
Fiberboard:		
Water ice packed	427	27,755
Dry ice packed	575	37,375

Costs to ship poultry in the various types of boxes per 100 lb. would be as follows:[3]

	Cents
Fiberboard boxes:	
Water ice packed	65.3
Dry ice packed	48.2
Polystyrene:	
Water ice packed	56.5
Dry ice packed	46.8

Total Costs

The costs of packaging materials; packing, loading, and unloading labor; coolant; transport per box; and total cost per 100 lb. are shown in table 6.

TABLE 6.—*Costs of packaging materials, direct labor (packing, loading, and unloading), coolant, and transport for water ice-packed and dry ice-packed poultry in fiberboard and polystyrene boxes, 1968*

Item	Fiberboard box		Polystyrene box	
	Water ice-packed	Dry ice-packed	Water ice-packed	Dry ice-packed
	Dollars	*Dollars*	*Dollars*	*Dollars*
Box and materials	0.478	0.467	[1] 0.550	[1] 0.550
Direct labor	.066	.070	.053	.057
Coolant	.063	[2].075	.038	[2].075
Transport	.424	.313	.367	.304
Total per box	1.031	.925	1.008	.986
Total per 100 lb.	1.59	1.42	1.55	1.52

[1] Estimated.

[2] Includes a 2.5-cent charge for use of dry ice machinery and one absorbent pad per box.

---

[3] Based on 1966 operating costs for trucks of 36 cents per mile reported by Camp(*3*) and 500 miles per average truck shipment from processing plant to market (*10*).

Although the water ice-packed polystyrene box would cost 7.2 cents more than the water ice-packed fiberboard box, the polystyrene box had a net saving of 4 cents per 100 lb. in total costs because less labor is required for packing, loading, and unloading; less ice is required; and transport costs are lower. However, the total costs of the dry ice-packed fiberboard boxes were 10 cents less than the dry ice-packed polystyrene boxes per 100 lb. This difference was due to the additional cost of the polystyrene boxes.

The dry ice-packed fiberboard boxes were 17 cents per 100 lb. less than the water ice-packed fiberboard boxes. The lower transport cost and lower cost of packaging material more than offset the additional cost of direct labor and dry ice snow. The dry ice-packed polystyrene boxes were 3 cents per 100 lb. less than the water ice-packed polystyrene boxes. The lower transport cost more than offset the additional cost of direct labor and dry ice snow.

General adoption of packing and shipping of dry ice-packed poultry in fiberboard boxes instead of water ice-packed poultry in fiberboard boxes would have resulted in an estimated annual saving of approximately $15.7 million for the 1968 production of fresh poultry. Most of this saving would result because more dry ice-packed poultry can be legally loaded per truck than water ice-packed.

Damage to Boxes

The six shipments contained approximately 2,600 fiberboard boxes and 200 polystyrene boxes. Most of these boxes were used for dry instead of water ice-packed poultry.

The fiberboard boxes with dry ice-packed poultry arrived at delivery points in better condition than the fiberboard boxes with water ice-packed poultry. Generally, the boxes that were packed with dry ice had less sag in the top and bottom and less creasing and crushing of corners than the fiberboard boxes that were water ice packed. Most of the damage to the water ice-packed fiberboard boxes was caused by the added weight of crushed ice and the melted ice water. In the dry ice-packed fiberboard boxes, the only drainage was the "drip" from the poultry and most of this was absorbed by the pad in the bottom of the box.

The polystyrene boxes arrived with about 2 percent slight damage and 1 percent serious damage. Slight damage consisted of chipped corners, cracked lids, sides, or bottoms, or any combination of these conditions. Seriously damaged polystyrene boxes were completely broken and could not be used to carry poultry for further distribution.

At the three processing plants and receivers' warehouses, both types of boxes were placed on pallets for storage. Fiberboard and polystyrene boxes were stacked on pallets four and five layers per pallet. Pallets of fiberboard boxes were sometimes double stacked, causing damage to the bottom boxes, but pallets of polystyrene boxes could not be double stacked because the bottom boxes could not withstand the added weight and would break.

Poultry Weight Loss and Temperature

The average weight loss of poultry in the six shipments was 6.3 percent in the dry ice-packed fiberboard and polystyrene boxes and 5.5 percent in the water ice-packed fiberboard and polystyrene boxes (table 7). This difference was statistically significant.

The average temperature of the poultry on arrival at the warehouse in the six shipments was 37° F. in the dry ice-packed fiberboard and polystyrene boxes, and 33° in the water ice-packed fiberboard and polystyrene boxes (table 8). This difference was statistically significant. In shipment 4, temperature of dry ice-packed and water ice-packed poultry on arrival at warehouses was the same. In this shipment the temperature of the poultry at the time of packing averaged 34° (table 8).

Various Amounts and Locations of Dry Ice Snow

The average temperature and percentage weight loss of poultry in two shipments with 3 lb. of dry ice snow in fiberboard boxes was the same as poultry packed in ice-packed fiberboard boxes (table 9). The temperature of the birds at the time of packing was 38° F. and ranged from 36° to 40°. With 14 oz. of dry ice snow per box, bird temperature and percentage of weight loss on arrival were higher, 38° and 6.4 percent compared with 33° and 5.9 percent for water ice-packed poultry.

TABLE 7.—*Weight loss of water and dry ice-packed poultry in fiberboard and polystyrene-foam boxes from processing plant to receivers' warehouses, 6 shipments, 1968*[1]

Shipment number	Percentage of weight loss in—				Time between loading and unloading the boxes
	Fiberboard box		Polystyrene box		
	Dry ice-packed	Water ice-packed	Dry ice-packed	Water ice-packed	
	Percent	*Percent*	*Percent*	*Percent*	*Hours*
1	6.5	5.4	6.6	4.7	44
2	6.1	5.6	6.9	5.7	68
3	6.5	5.7	5.9	5.7	46
4	6.3	5.7	5.6	5.4	48
5	6.5	5.4	6.2	5.8	20
6	6.0	5.3	6.8	5.8	22
Mean	6.32 a	5.52 b	6.33 a	5.52 b	----

[1] Mean of 5 boxes. Means followed by different letters are significantly different at 1-percent level.

TABLE 8.—*Temperature of poultry at packing in processing plant and on arrival at receivers' warehouses in water ice-packed and dry ice-packed fiberboard and polystyrene-foam boxes, 6 shipments, 1968*[1]

Shipment number	Range of temperature of birds during packing	Temperature on arrival at warehouse				Time between loading and unloading the boxes
		Fiberboard box		Polystyrene box		
		Dry ice-packed	Water ice-packed	Dry ice-packed	Water ice-packed	
	°F.	*°F.*	*°F.*	*°F.*	*°F.*	*Hours*
1	36-41	38	32	38	33	44
2	35-40	37	33	37	33	68
3	35-39	37	33	37	33	46
4	33-35	33	33	33	32	48
5	36-39	39	33	39	32	20
6	36-40	38	33	39	33	22
Overall mean		37 a	33 b	37 a	33 b	----

[1] Mean of 5 boxes. Means followed by different letters are significantly different at 1-percent level.

TABLE 9.—*Temperature and percentage weight loss of poultry packed in fiberboard boxes with different amounts of dry ice snow on top and bottom of box and with water ice, 2 shipments, 1968*[1]

Location of dry ice snow in box and shipment number	Dry ice-packed poultry						Water ice-packed poultry	
	14 oz.		2 lb.		3 lb.			
	Temperature	Weight loss	Temperature	Weight loss	Temperature	Weight loss	Temperature	Weight loss
	°F.	*Percent*	*°F.*	*Percent*	*°F.*	*Percent*	*°F.*	*Percent*
Top:								
1	38	5.9	33	6.0	31	5.2	33	5.3
2	37	6.4	33	6.3	32	6.6	33	6.5
Mean	38	6.2	33	6.2	32	5.9	33	5.9
Bottom:								
1	38	6.0	35	5.9	33	5.0	----	----
2	38	7.0	35	7.1	33	6.6	----	----
Mean	38	6.5	35	6.5	33	5.8	----	----
Overall mean	38	6.4	34	6.4	33	5.9	33	5.9

[1] Mean of 3 boxes within each shipment, 4 temperatures per box, 2 birds from each layer.

No meaningful difference was found in percentage of weight loss of poultry in comparing dry ice snow put in the bottom of the box to snow put on top the poultry (table 9). However, temperature of the birds was slightly lower when the dry ice snow was put on top the poultry than in the bottom of the box. This may be explained by the tendency of cold air to flow downward.

Trade Reaction

The three warehouse receivers preferred the dry ice-packed poultry because the pack was lighter in weight, had less drainage from boxes, and appeared more sanitary. With water ice-packed poultry, boxes leaked melted ice water and bird drainage when the boxes were lifted. The receiver was very pleased with the bird temperature of the dry ice-packed poultry in shipment 4. The receivers of the other shipments were displeased with the higher temperatures of the dry ice-packed poultry compared with the water ice-packed poultry.

All the warehouse receivers preferred the fiberboard boxes because the polystyrene boxes damaged easily and had to be handled more carefully. The polystyrene boxes could not be thrown onto pallets or into and out of trucks.

The eight retail receivers preferred the dry ice-packed rather than the water ice-packed poultry because the boxes were lighter and had less drainage and thus lower contamination of holding coolers, and the appearance of the poultry was superior to water ice-packed poultry. The poultry in water ice-packed boxes appeared crushed and "washed out." Most retailers said the polystyrene boxes appeared more sanitary and were easier to handle because they were lighter than the fiberboard boxes.

DISCUSSION

The concept of shipping iceless fresh poultry has been studied for many years. Processing firms now have refrigeration, important in the handling of fresh poultry. They have increased their cooler capacities around 35° F. Most trailers hauling fresh poultry are refrigerated or at least insulated. Warehouses and distribution facilities also have improved refrigeration equipment.

These handling, storing, and shipping improvements have made possible further advances in the concept of shipping iceless fresh poultry. Shipping "chill-pack" poultry is predicated on the use of good refrigeration at the temperature range of 28° to 30° F. The use of dry ice, 14 oz. of dry ice snow per box, also is predicated on good refrigeration. Another assumption is that the temperature of poultry be 34° to 35° at the time of packing. Most plants are now equipped with continuous chillers which can cool poultry to 34° to 35°.

If dry ice snow is used as a coolant, 3 to 5 pounds of dry ice snow per pox would offset any cost advantage of dry ice-packed poultry. However, if temperature of poultry at time of packing is 34° to 35° F. and temperature in shipping and handling is maintained at approximately 30°, the dry ice system with 14 oz. of dry ice snow per box is promising. The elimination of water ice in shipping increases the amount of poultry which can be loaded per truck approximately by 25 percent and can reduce transport costs from 65.3 to 56.5 cents per 100 lb. of poultry. The value of this saving would more than offset any additional cost of dry ice and the slightly increased shrinkage experienced in the commercial shipments from processing plant to receivers' warehouses.

LITERATURE CITED

(1) Burkhart, D.
1966. Dry ice cuts chill-pack costs for park poultry. Broiler Indus. 29 (10): 25–27.

(2) Butler, D. C., Bratzler, L. J. and Mallmann. W. L.
1953. The effect of bacteria on the color of prepackaged retail beef cuts. Food Tech. 7 (10): 397–400.

(3) Camp, T. H.
1964. Motor truck operating costs of farmer cooperatives. U.S. Farmer Coop. Serv. Gen. Rpt. 121, 9 pp.

(4) Davis, B. H.
1963. Iceless pack for fresh broilers. Broiler Business 14 (10): 18–20, 24, 26, 28.

(5) Duncan, D. B.
1955. Multiple range and multiple F tests. Biometrics 11: 1–52.

(6) May, K. N., Powell, W. R., and Hudspeth, J. P.
1966. A comparison of quality of fresh chicken packed in various containers. Ga. Agr. Expt. Sta. Bul. N.S. 168, 19 pp.

(7) McKee, R. C., Conkey, J., and Carlson, J. A.
1959. A study of the comparative shelf life of wet- and dry-packed poultry. Poultry Sci. 38 (2): 260–271.

(8) Risse, L. A.
1968. Cost and performance of polystyrene boxes for shipping ice-packed poultry. U.S. Dept. Agr. Market. Res. Rpt. 833, 8 pp.

(9) Shantz, R. C., Anderson, G. W., Orr, H. L., and Fuller, G. W.
1967. An evaluation of the dry pack and ice pack for storing fresh broilers (abstract). Poultry Sci. 46 (5): 1318.

(10) Snitzler, J. R., and Byrne, R. J.
1958. Interstate trucking of fresh and frozen poultry under agricultural exemptions. U.S. Dept. Agr. Market. Res. Rpt. 224, 88 pp.

(11) Thomson, J. E., Mercuri, A. J., and Risse, L. A.
1968. Shipping containers for ice-packed poultry—effect on microbial counts and weights of poultry and ice. U.S. Dept. Agr. Market. Res. Rpt. 811, 12 pp.

(12) United States Department of Agriculture.
1969. Poultry and egg situation. U.S. Dept. Agr. PES 257, 35 pp. June 1969. Washington, D.C.

☆U.S. GOVERNMENT PRINTING OFFICE: 1971 O—403-591

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Hyattsville, Maryland 20782

Official Business
Penalty for Private Use, $300

POSTAGE & FEES PAID
United States Department of Agriculture